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Spacebased Sea Surface Salinity Depicts Freshwater Changes in the Hudson Bay

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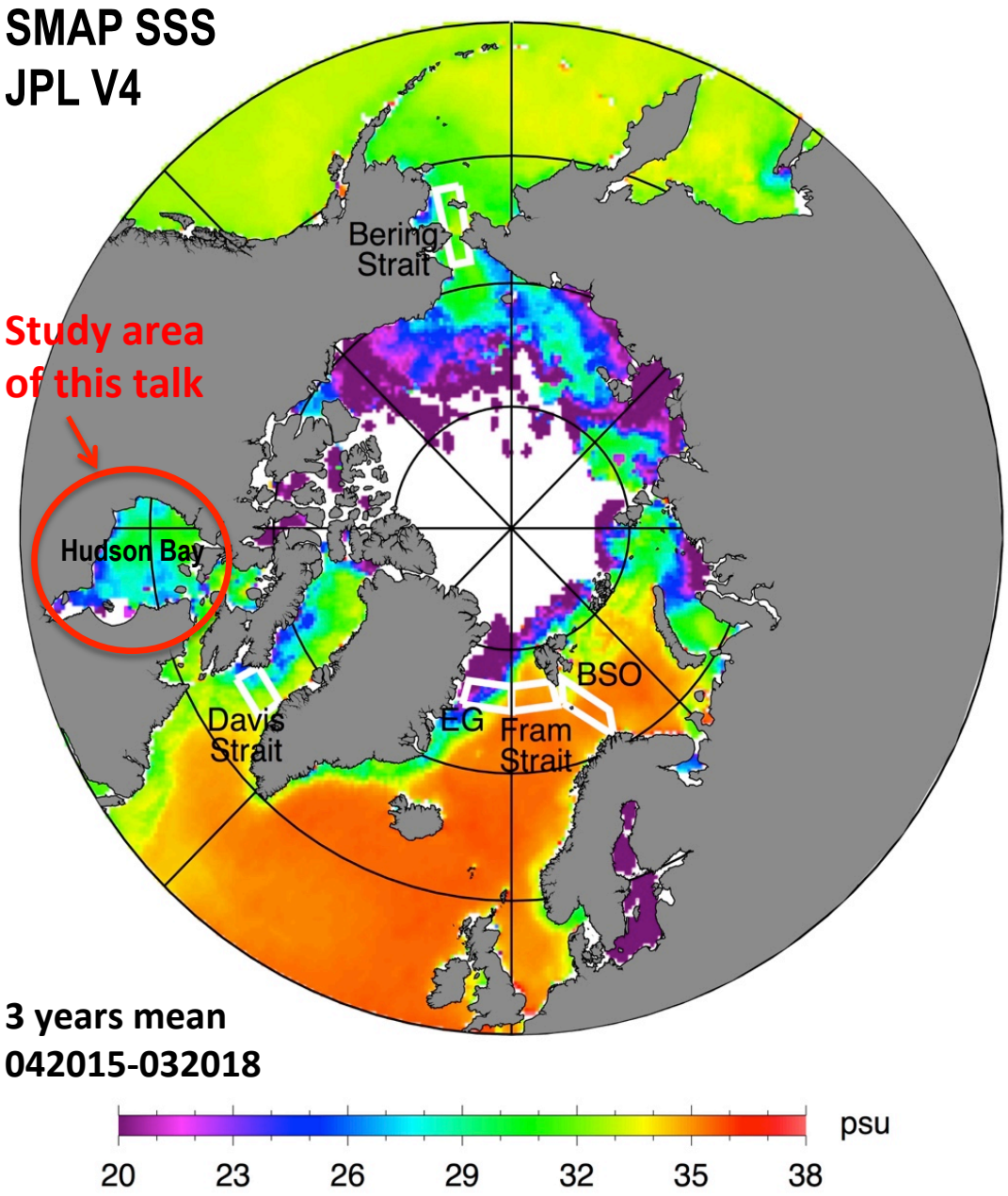
Introduction



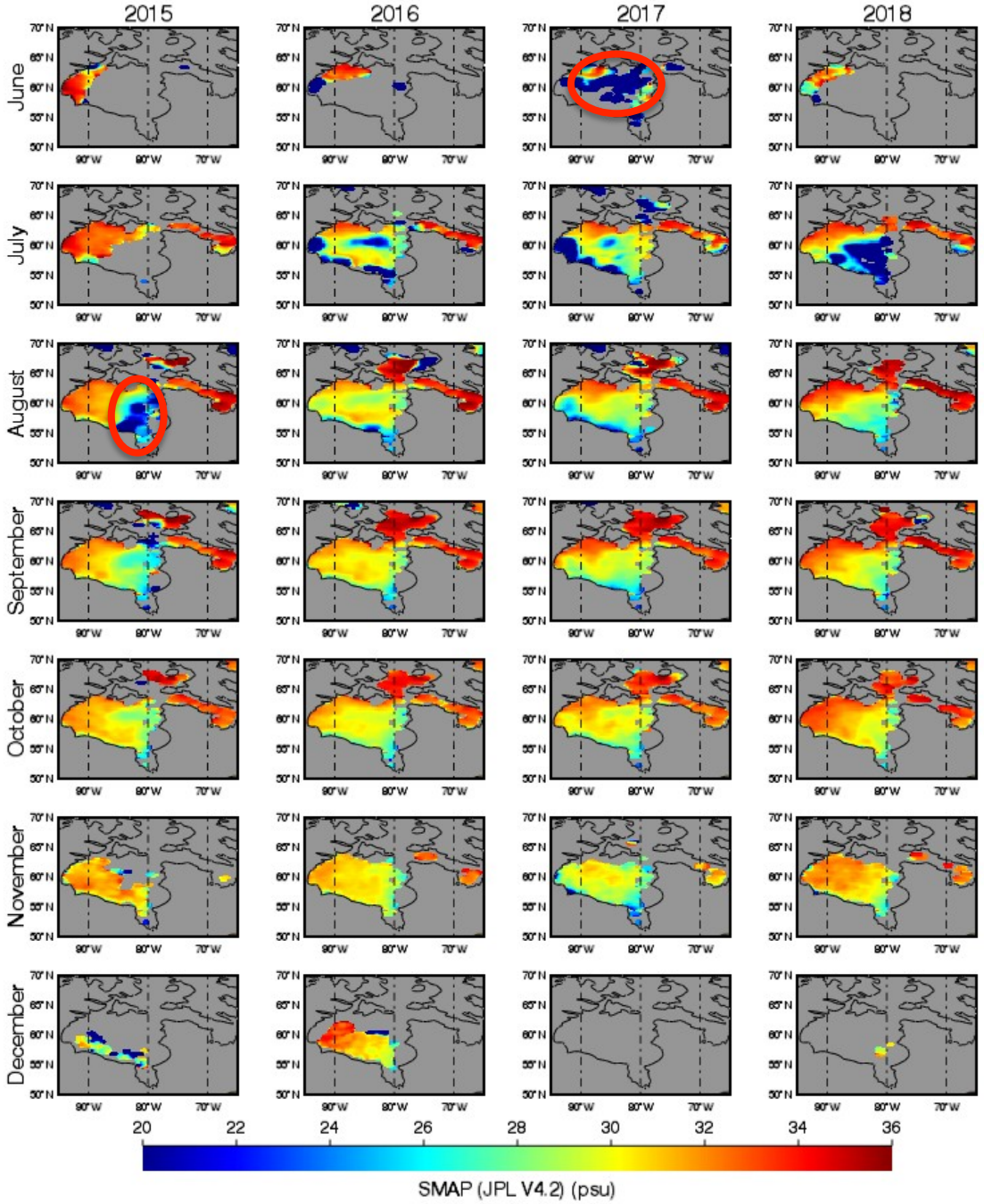
Satellite remote sensing is highly desired to play a significant role in monitoring the rapid changes in the Arctic Ocean where sea surface salinity is one of the critical environmental variables, linking various freshwater components.

L-band microwave sensitivity to seawater salinity largely degrades in cold water and suffers from sea ice contamination.

Despite SSS uncertainty (~1 psu) in Arctic Ocean by current operational missions (SMAP & SMOS), we found large SSS variability in Arctic gateways agree with available mooring data, demonstrating the potential utility of satellite SSS in monitoring Arctic freshwater [Tang et al., 2018; Olmedo et al, 2018]

This study focuses on the SSS response to the freshwater seasonal cycles and anomaly in the Hudson Bay

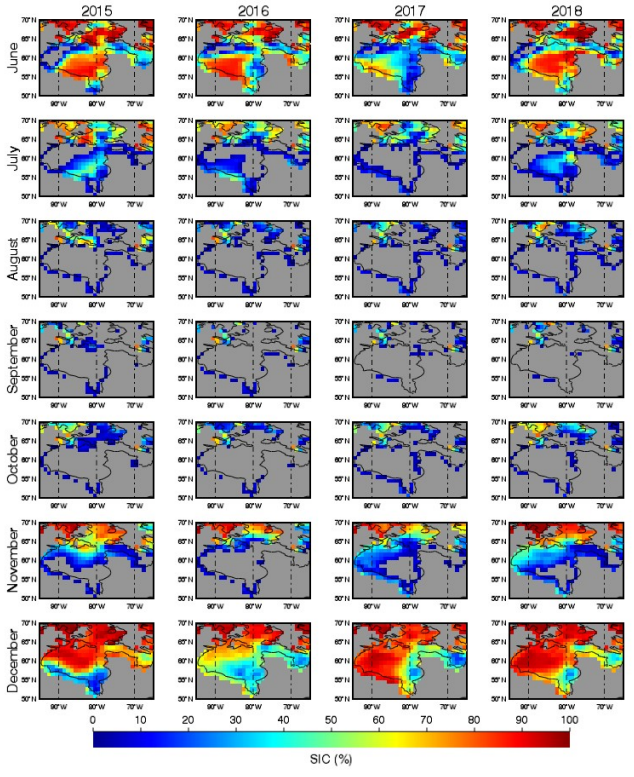
SMAP JPL V4.2 SSS in the Hudson Bay during ice thaw seasons 2015-2018

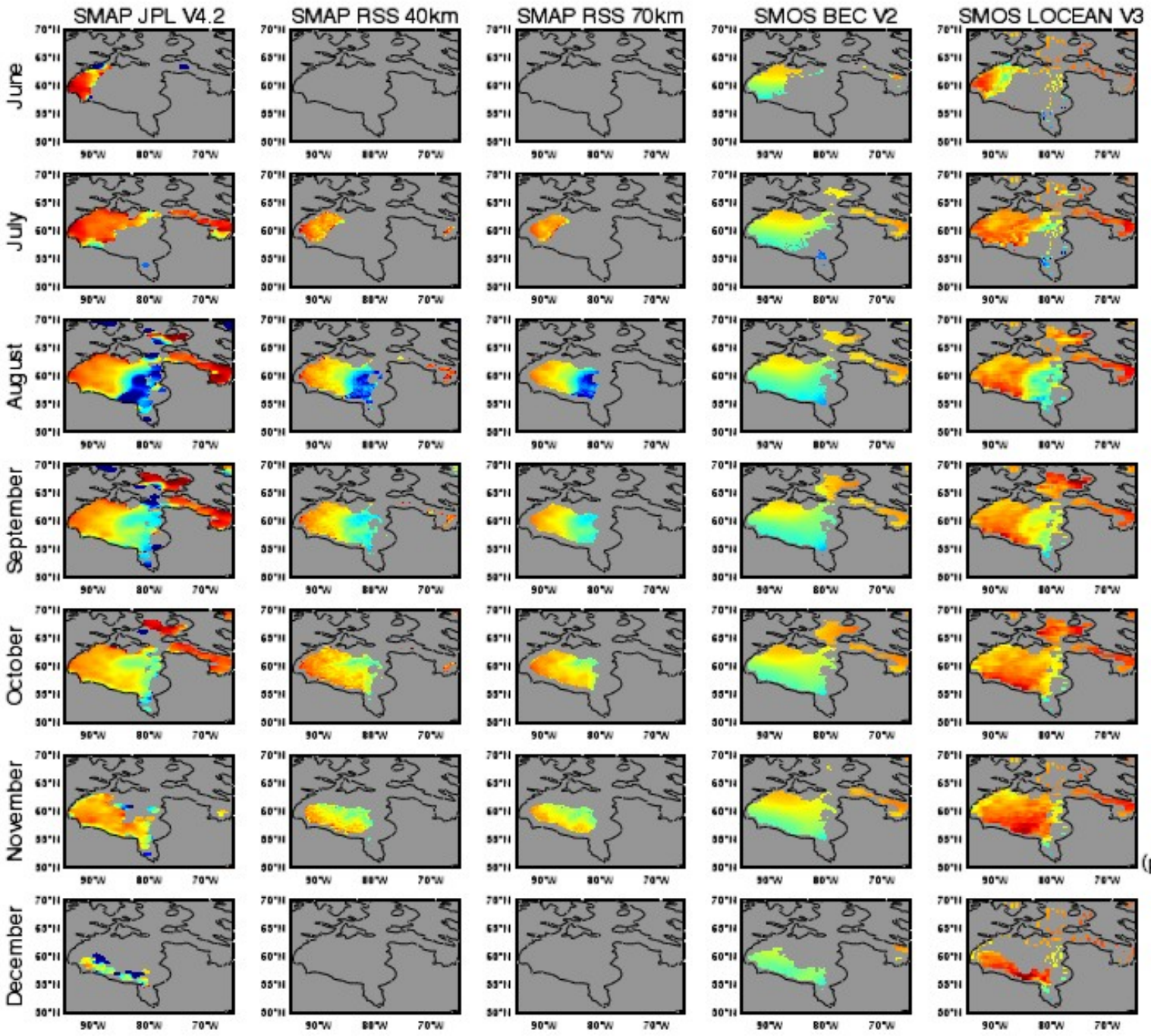


SMAP (JPL V4.2) show several patches of extreme low SSS values in the Hudson Bay, early in the summer.

Are those real fresh signatures or due to undetected sea ice contamination?

Sea Ice Concentration (NSIDC)





2015

SSS in the Hudson Bay from 5 satellite SSS products

What can we learn from differences between products?

There is no in-situ salinity data currently available

Hudson Bay

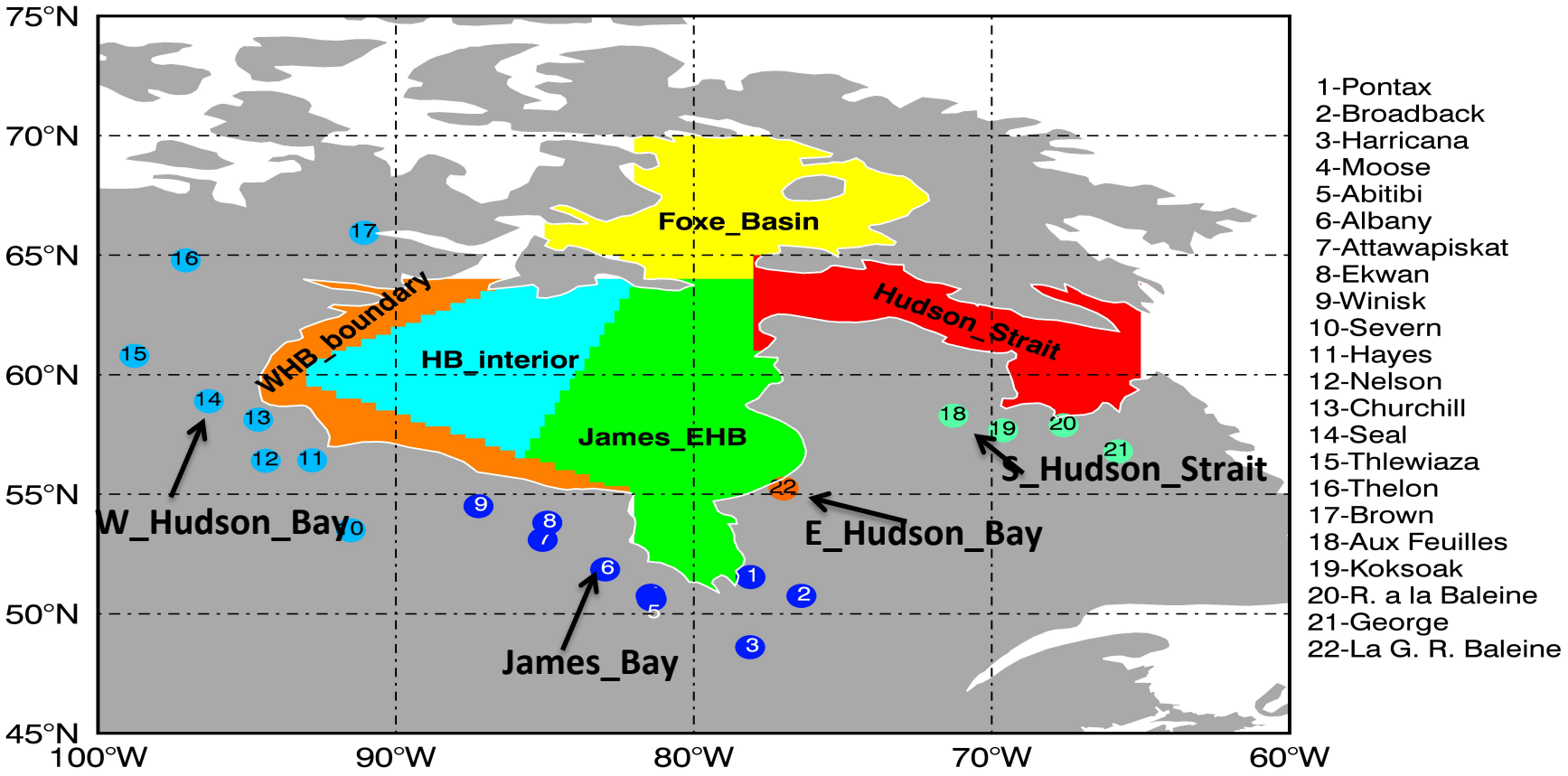
Surface area: 819,000 km^2
Depth: average 120 m, maximum 250 m
Ice thickness: average 1.0m, maximum 1.6 m

- A large inland sea connected to Arctic ocean via Foxe basin and the North Atlantic via Hudson Strait. Hudson Bay freezes over completely in the winter but thaws for periods in the summer. Vast amounts of freshwater runoff flowing in from terrestrial river systems.
- Located south of the Arctic circle, climate change in the Hudson Bay is evident:
  - air temperature have risen ~1°/ decade;
  - season of sea-ice cover is shortened; and
  - dramatic changes in the timing and volume of river runoff
- Bridging the Arctic and temperate domains of central Canada, Hudson Bay therefore represents an important sentinel of cryospheric change [Macdonald et al., 2011]

Objective: Use Hudson Bay as a test bed, to investigate the potential utility of current satellite SSS products in monitoring freshwater components in polar region, and identify areas for future improvements

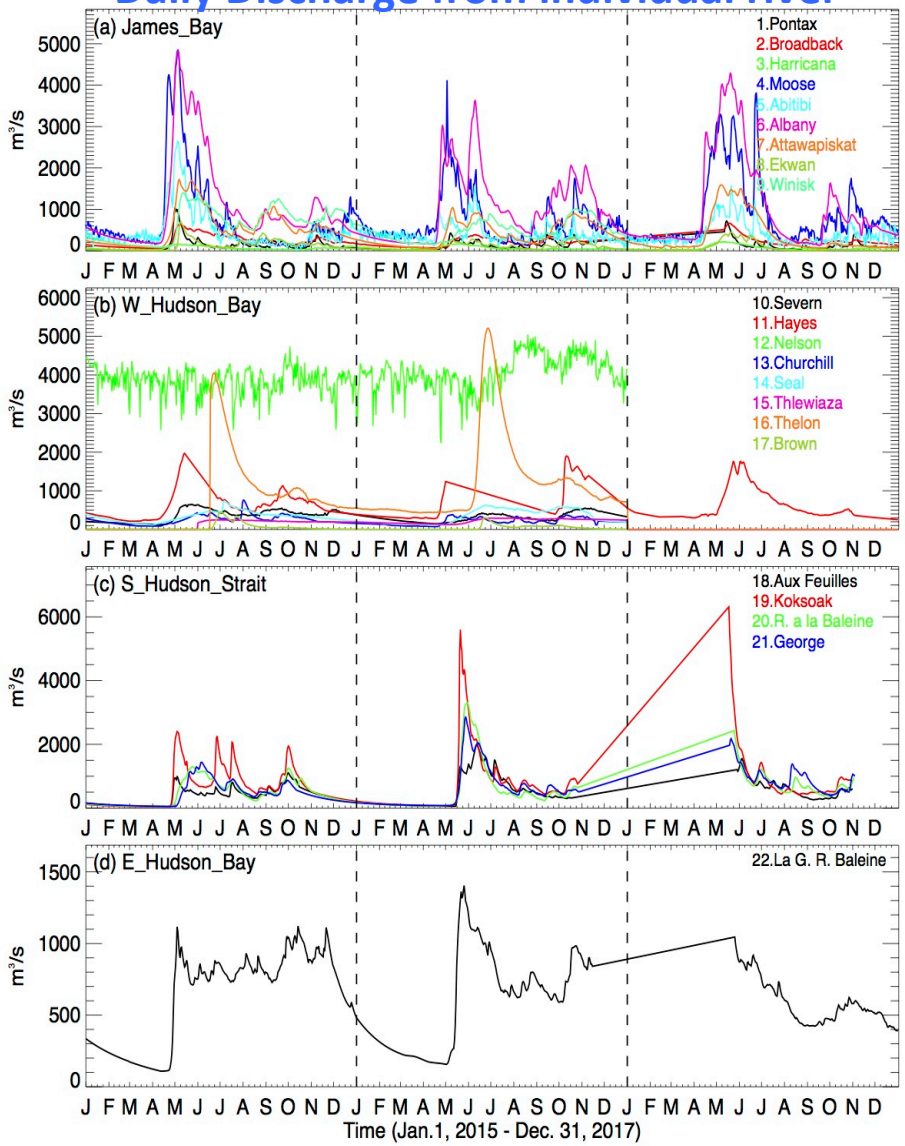
Approach: We examine SSS feature in the context of independently measured freshwater components in the Hudson Bay:

- Daily river discharge from all rivers surrounding the Hudson Bay
- Monthly Precipitation (P), evaporation (E), and the net surface forcing (P-E)
- Freshwater contribution from sea ice change derived from sea ice concentration

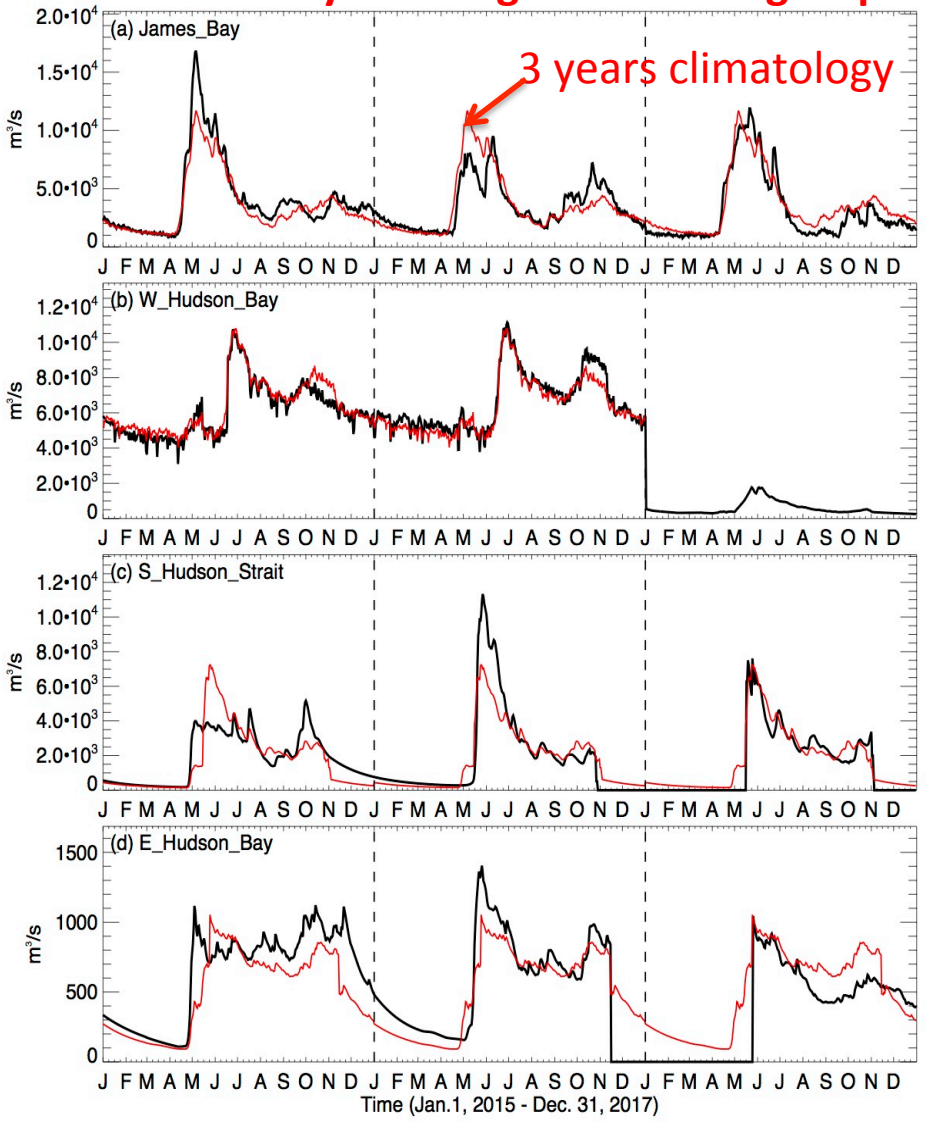


Freshwater input from river discharges

Daily Discharge from individual river

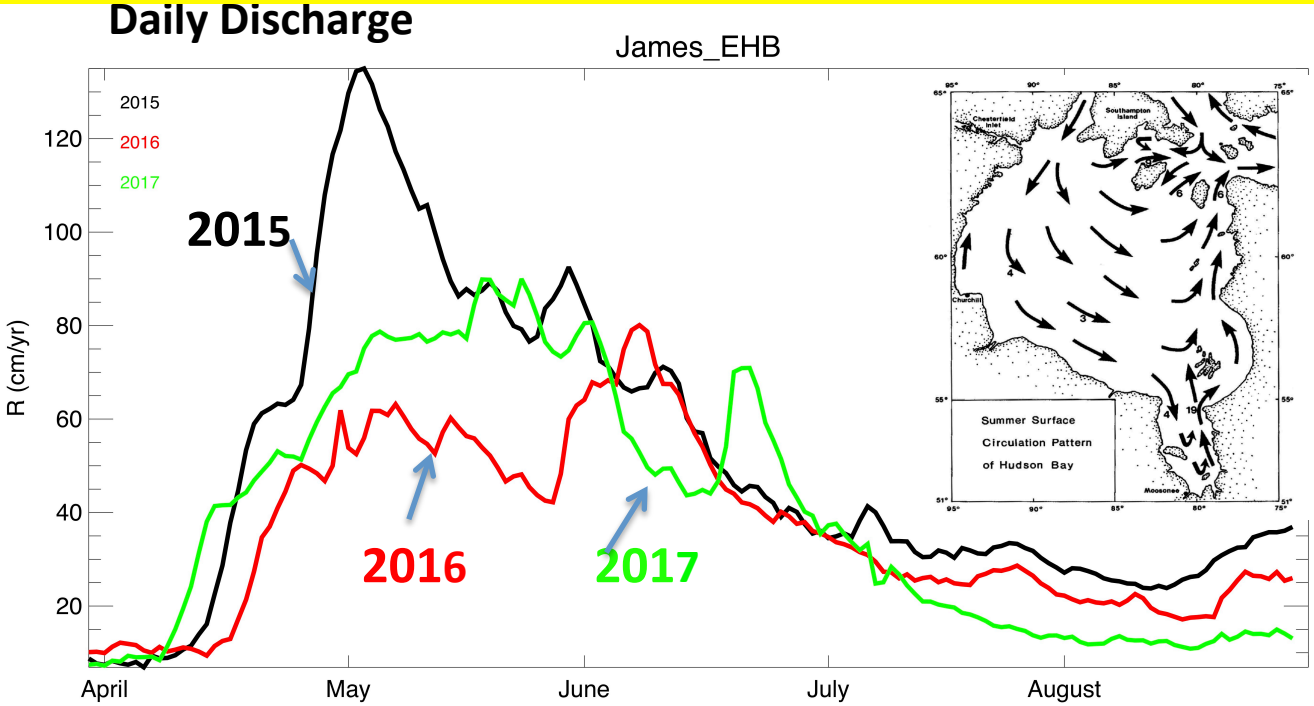


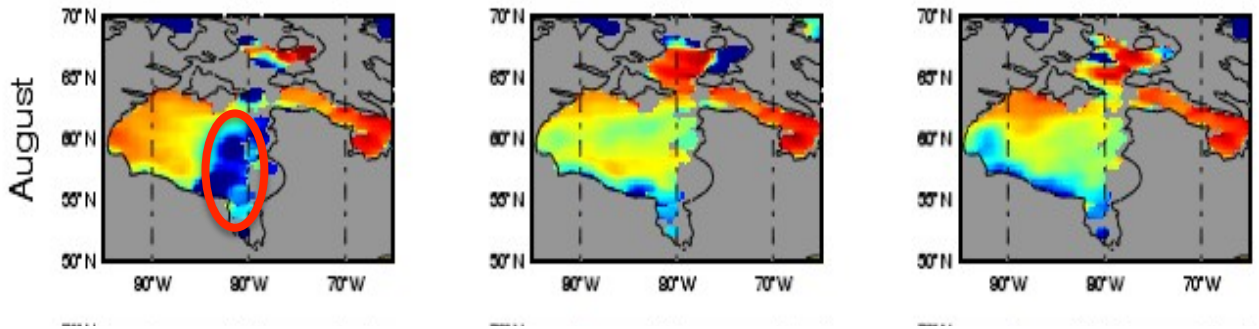
Combined daily discharge from river groups



3rd year of discharge data of some river west of the Hudson Bay is not available

SSS response to river discharge



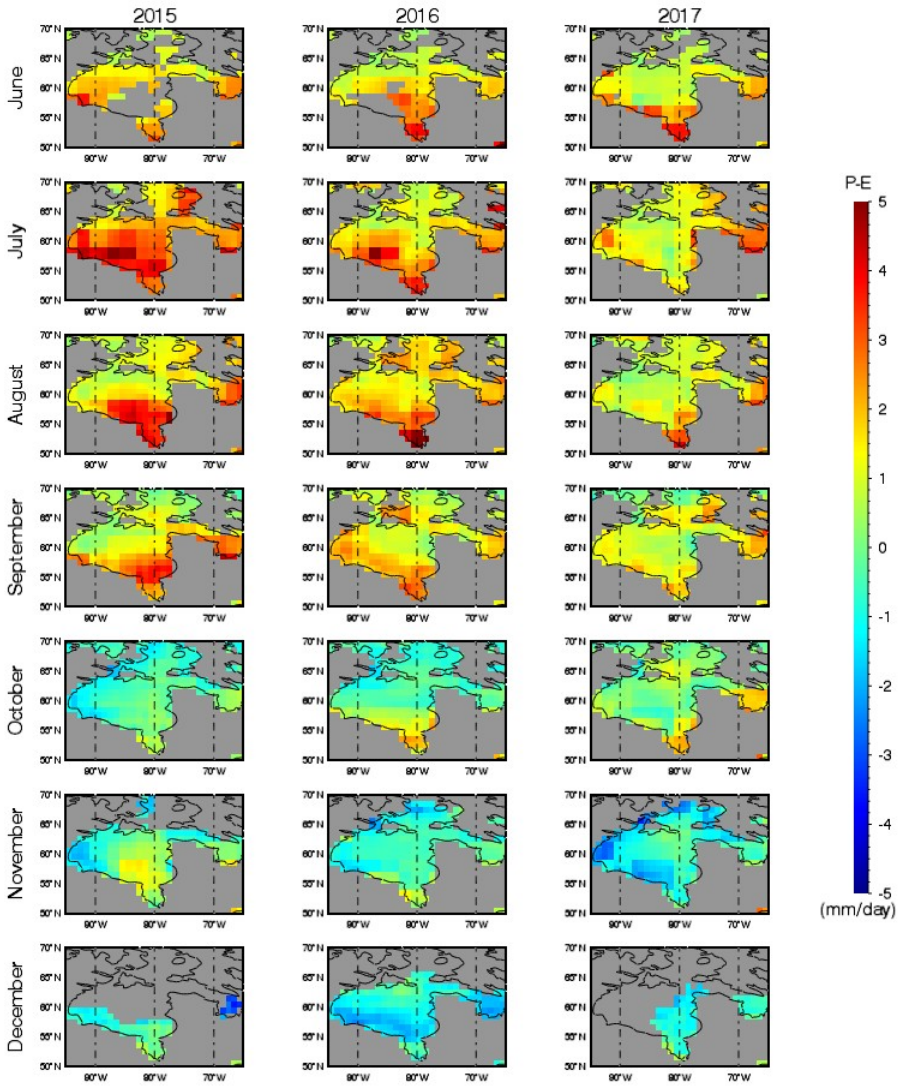


SMAP SSS (JPL V4.2)

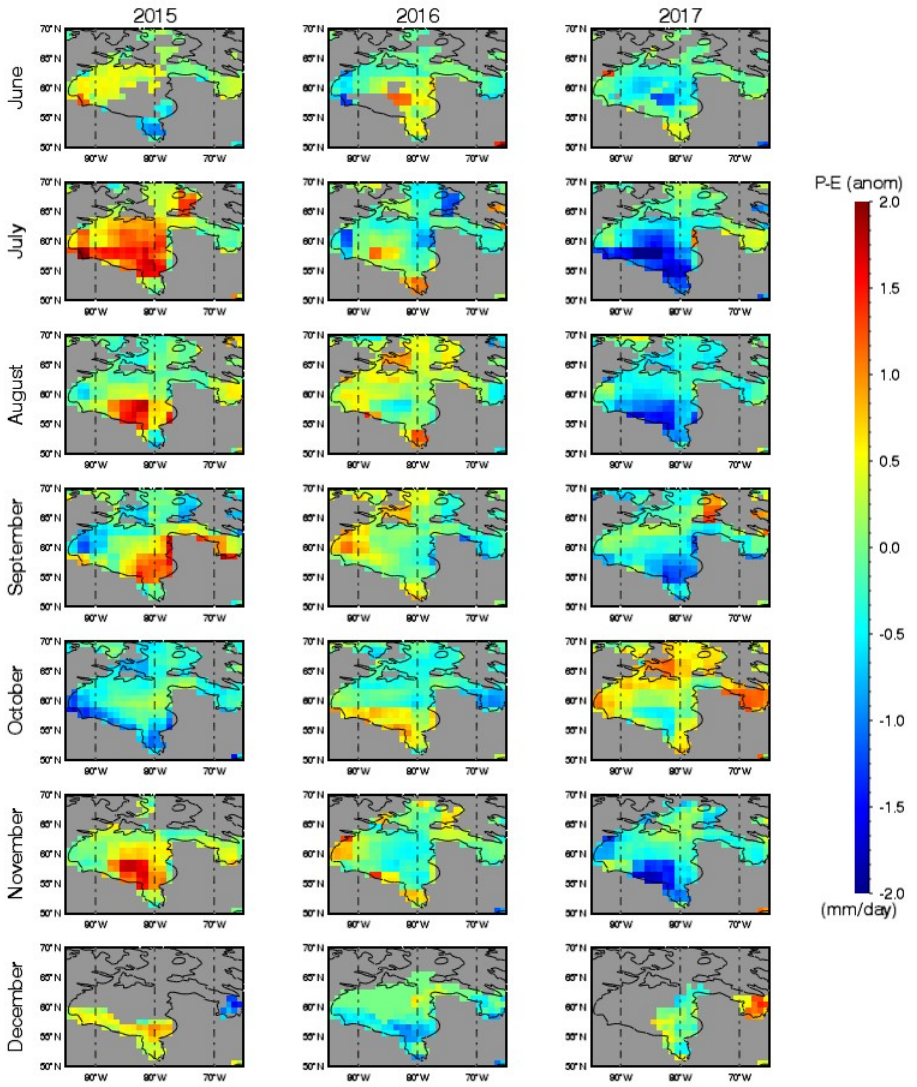
- The extreme fresh signature in SSS along the path (from James Bay northward to the Hudson Strait) is consistent with with the abnormal positive discharge from southern rivers
- Integrated from April to August, rivers around the James Bay brought in 80.4 km^3 freshwater in 2015, which is 13.6 km^3 or 20% more than the three years' average
- James Bay river discharge peaked in May 2015, three months ahead of the low SSS observed by SMAP. Because the Hudson Bay was covered by ice, satellite was not able to observe the progress of river plume.

Surface freshwater forcing (P-E) in the Hudson Bay

P – E



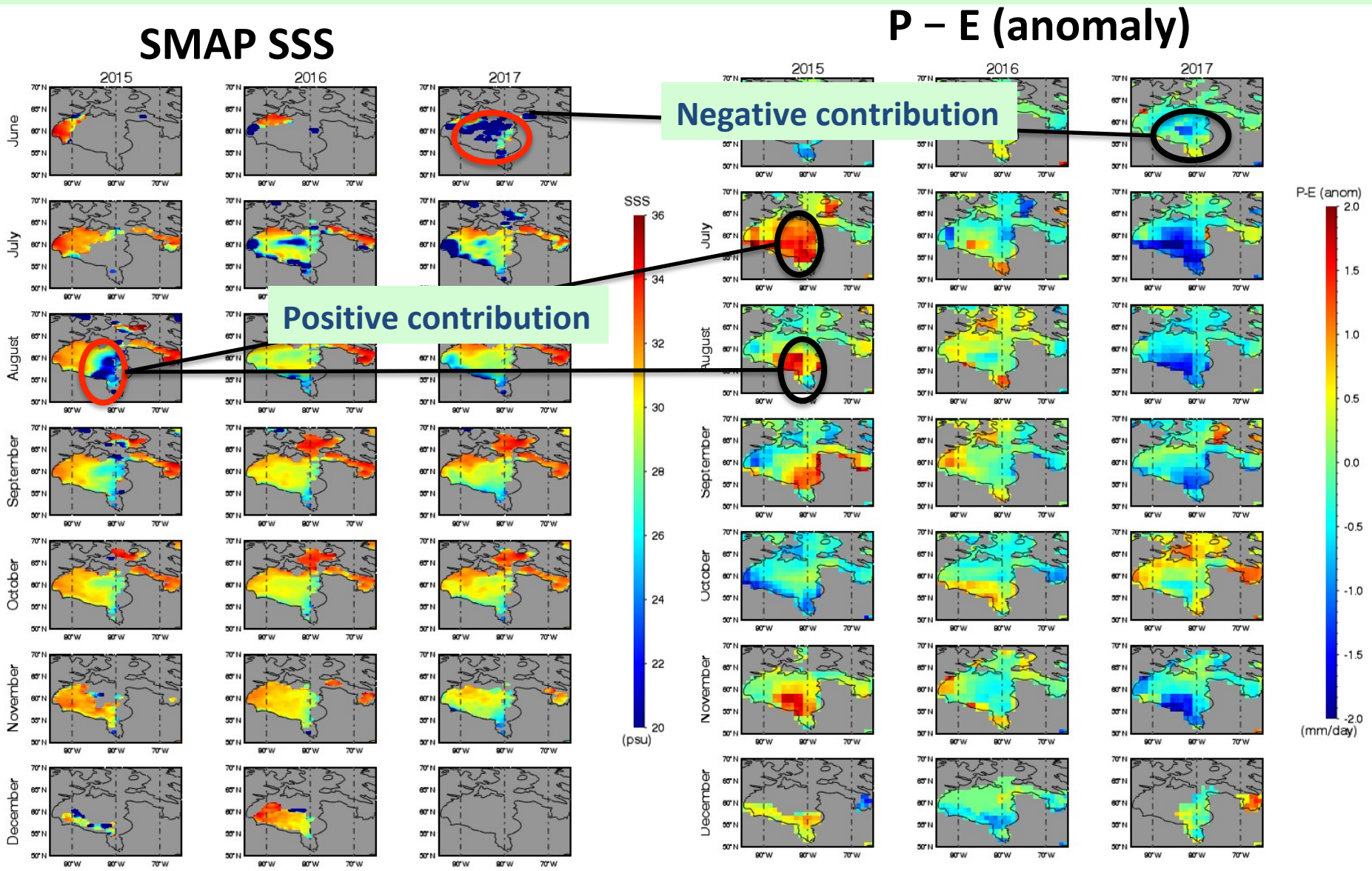
P – E (anomaly)



P: CMAP monthly

E: OAflux

SSS response to surface forcing P-E



P-E anomaly in Hudson Bay contributes positively to August 2015 fresh signature, but slightly negative to the 2017 summer early melt

Freshwater input from sea ice change

The freshwater input from local sea ice changes, I_{local}, is roughly estimated from sea ice concentration, assuming a uniform ice thickness of 1 m (~previous knowledge of average thickness cross the bay):

$$I_{local} = \frac{\left(C(t_2,x,y)h_{ice}(t_2,x,y) - C(t_1,x,y)h_{ice}(t_1,x,y)\right) \cdot Area \cdot \rho_{ice}}{Area \cdot \rho_{ice} \cdot (t_2 - t_1)}$$

C(t,x,y): monthly sea ice concentration
h_{ice}: sea ice thickness
ρ_{ice}: density of ice

Freshwater input from sea ice change

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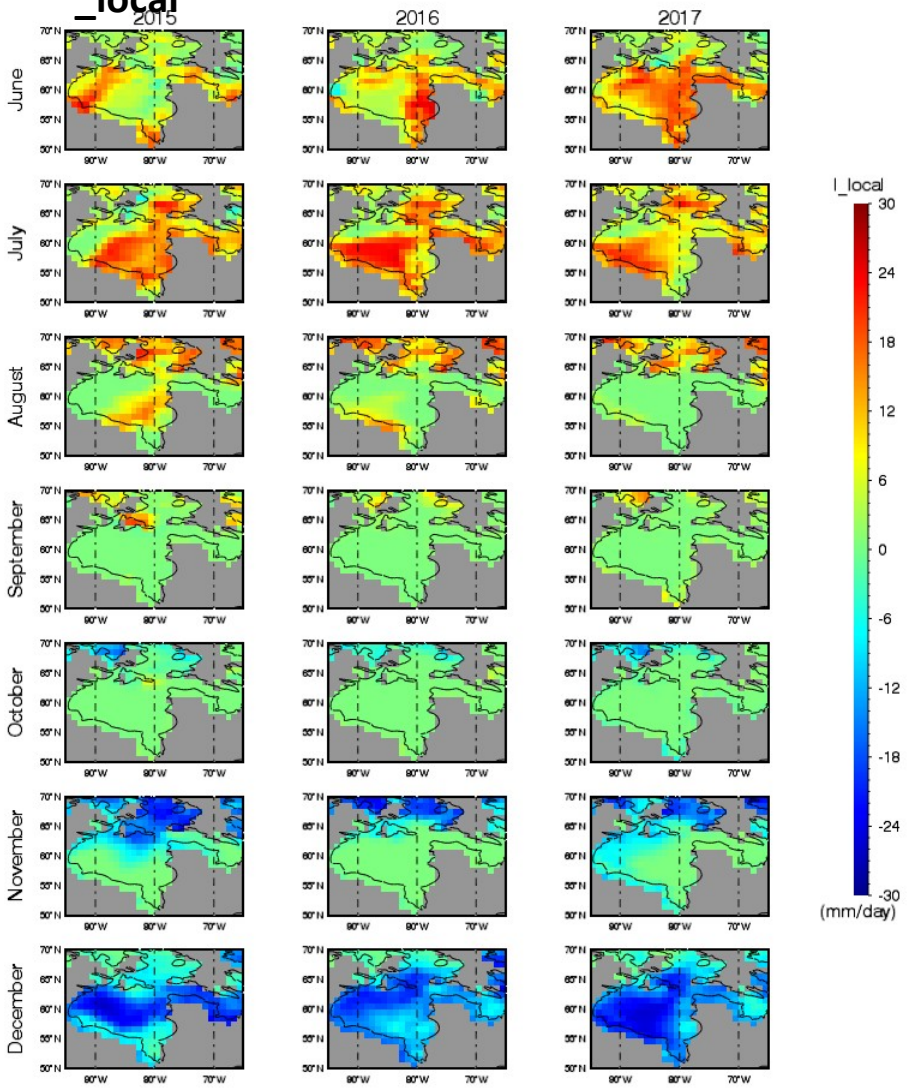
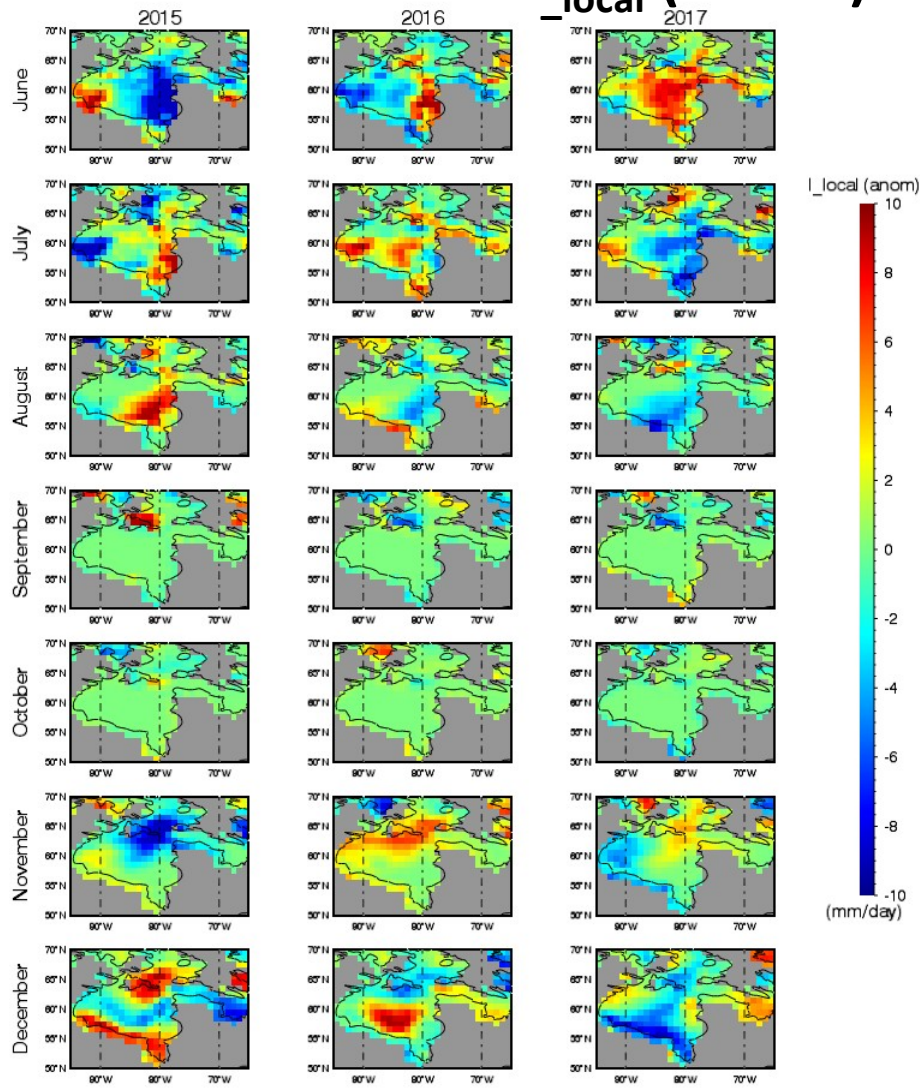
I_local



I_local (anom.)



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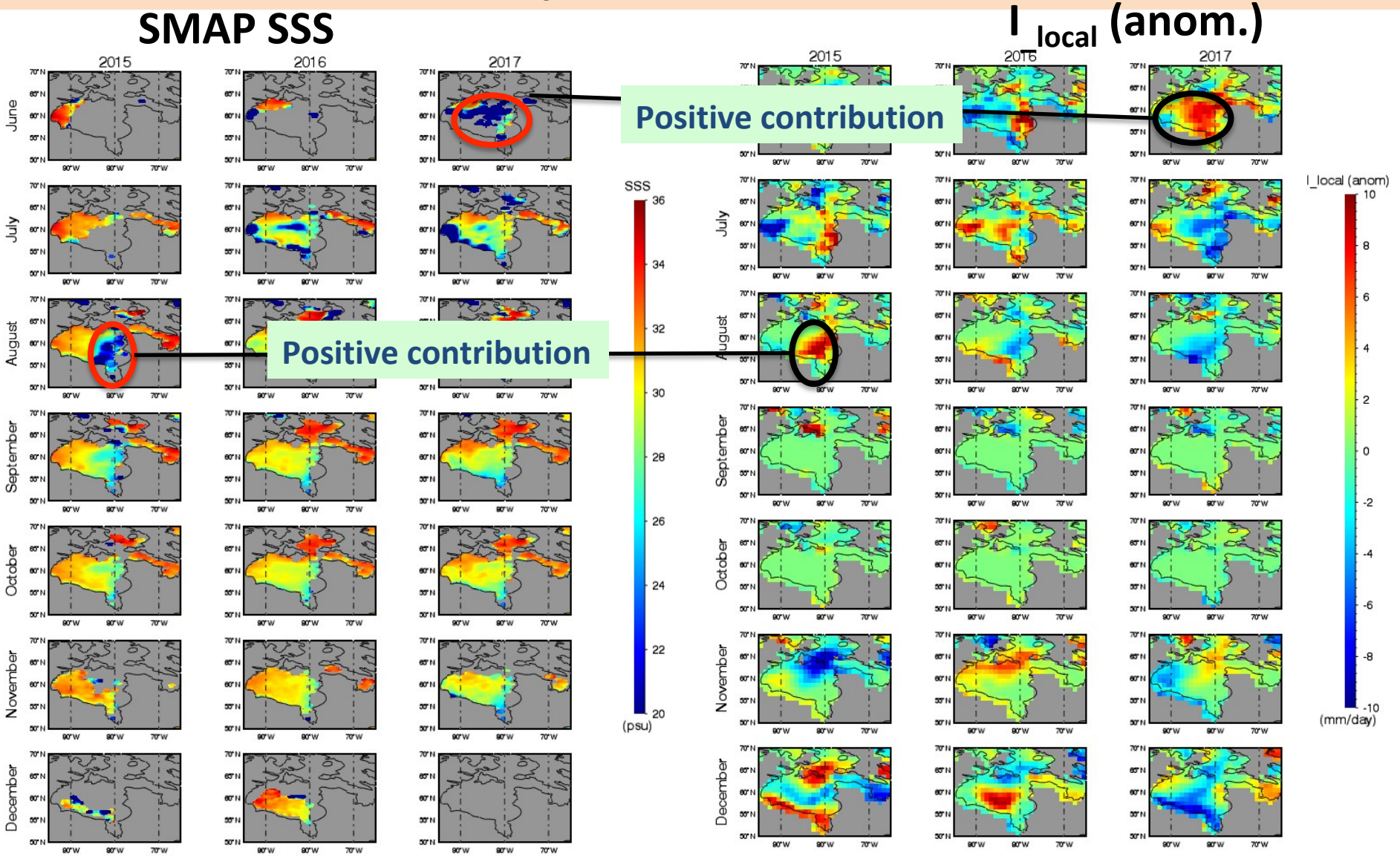
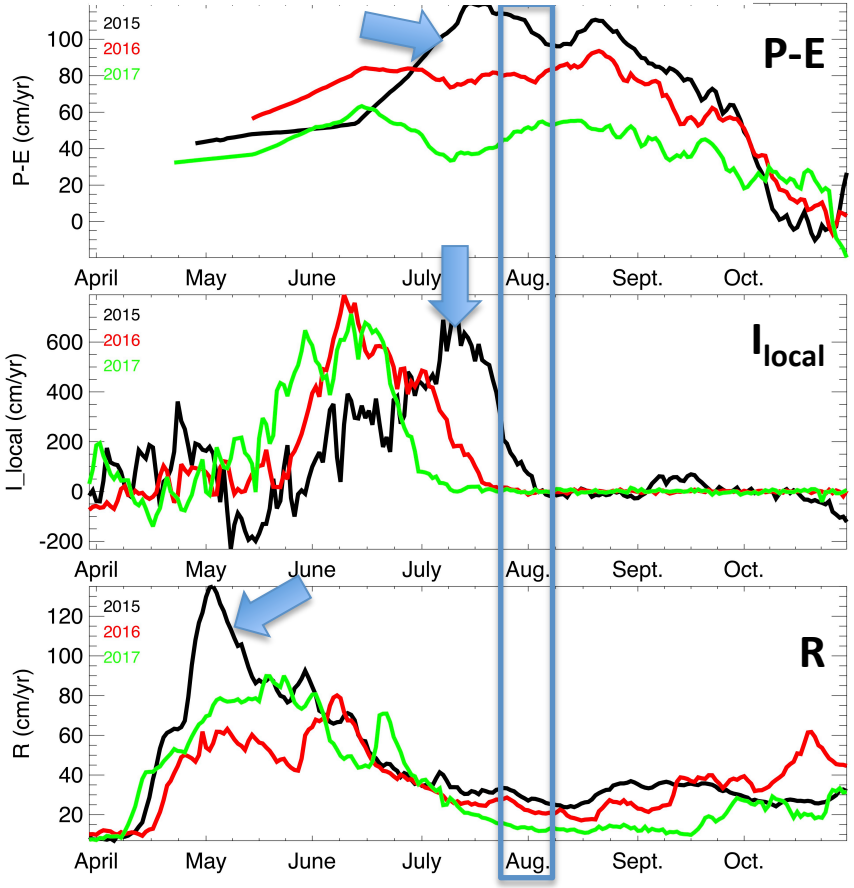
SSS response to sea ice melt



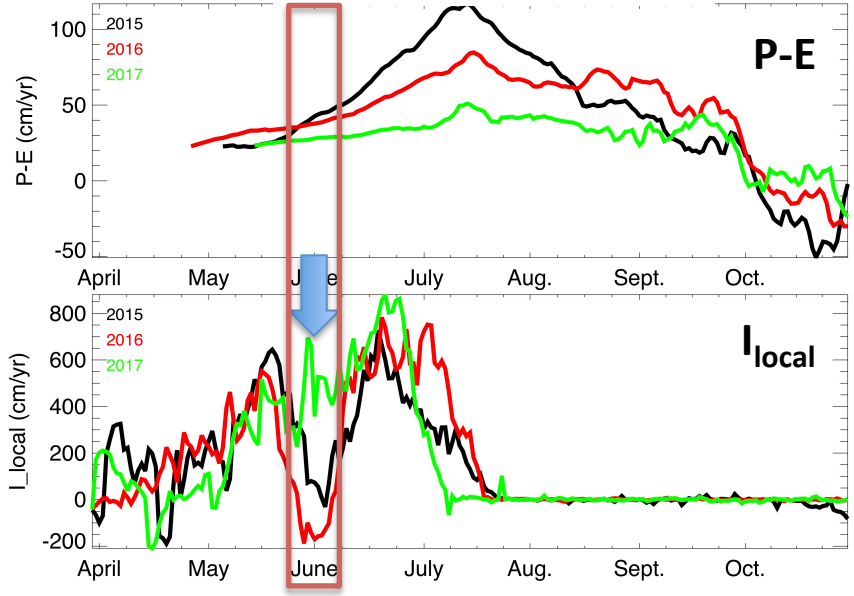
Early onset of sea ice melting in June 2017 created anomalous positive freshwater input in the interior of Hudson Bay, resulting low SSS. The late ice melt onset in 2015 (Aug.) is also consistent with low SSS

SSS reflect combined effect of regional freshwater seasonal cycles anomaly of various processes

James and eastern Hudson Bay

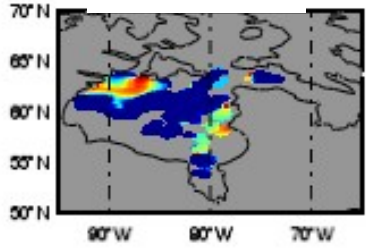


Hudson Bay Interior

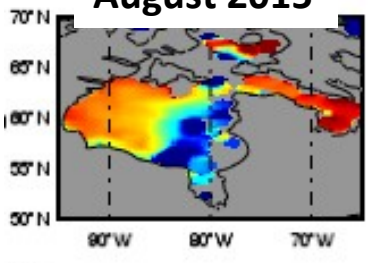


Early sea ice melt in June 2017 is responsible for the extremely low SSS

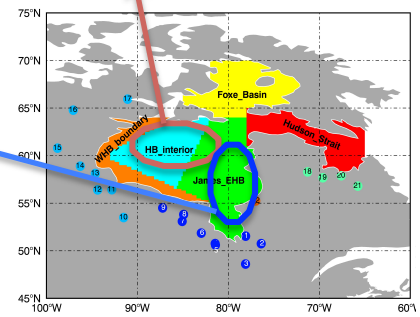
June 2017



August 2015



All components of freshwater supports anomalous fresh signature in August 2015 (differ in time)



Integrate over area of each sub-regions the freshwater inputs from: surface forcing (P-E), sea ice (I_{local}) and river discharge (R)

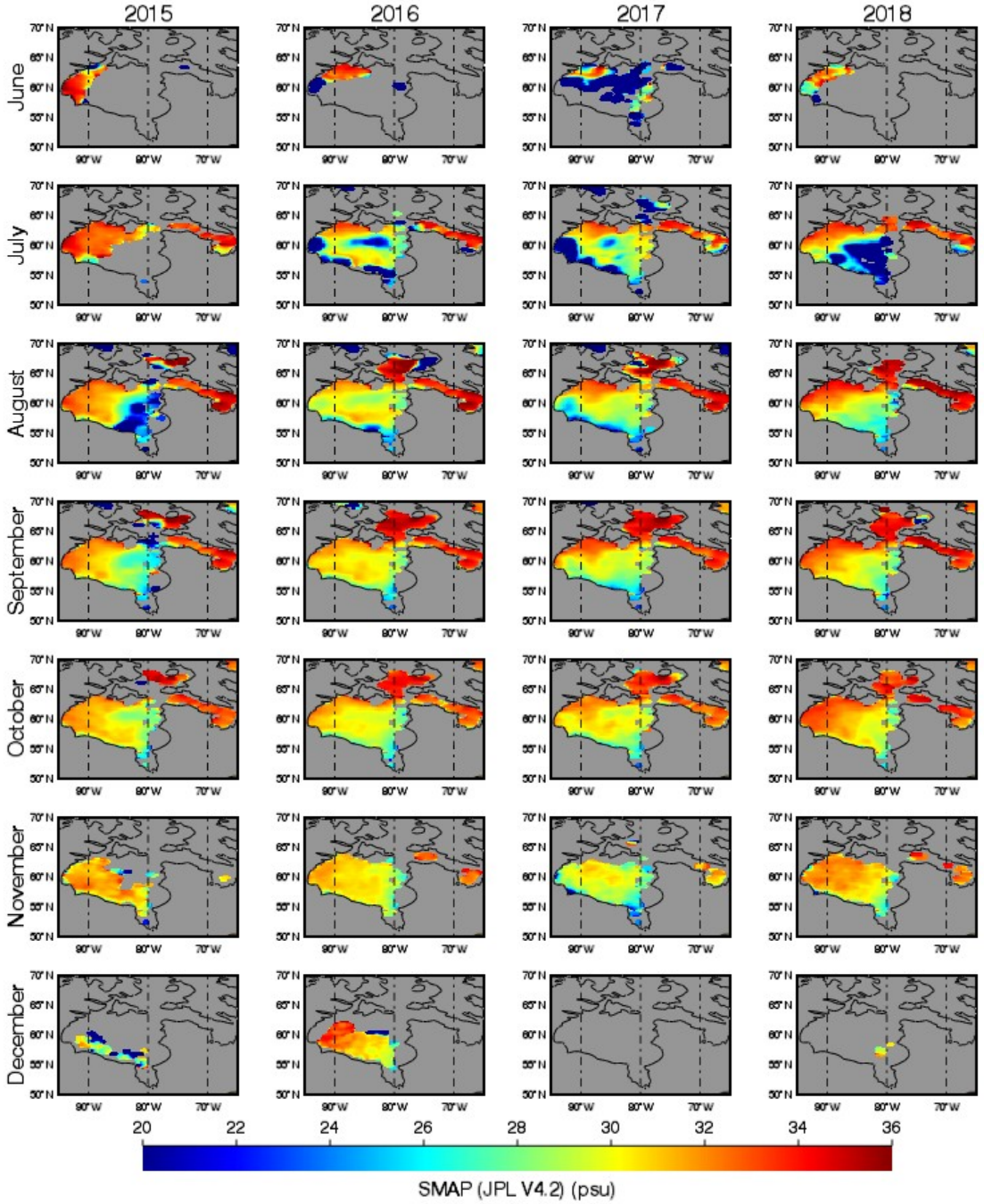
Summary

- SSS retrieved from SMAP and SMOS in the detects freshwater seasonal cycle anomaly in the Hudson Bay, encouraging further exploration of the potential utility from current mission in monitoring changes in the Arctic Ocean
- Further improvement of retrieval algorithm for satellite SSS products in polar-region, e.g.
  - Relax the requirement of sea ice concentration for SSS retrieval
  - Implement sea ice correction to account for the emissivity difference between ice (unwanted) and open water (used for retrieval)
  - Consider the rapid changes Arctic Ocean is experiencing when constrain the SSS retrieval by climatology (various forms)

Backup slides: SSS in the Hudson Bay from five satellite products

- SMAP JPL V4.2
- SMAP RSS V2 40km
- SMAP RSS V2 70km
- SMOS BEC V2
- SMOS LOCEAN debiase V3

SMAP JPL V4.2 SSS in the Hudson Bay during ice thaw seasons 2015-2018



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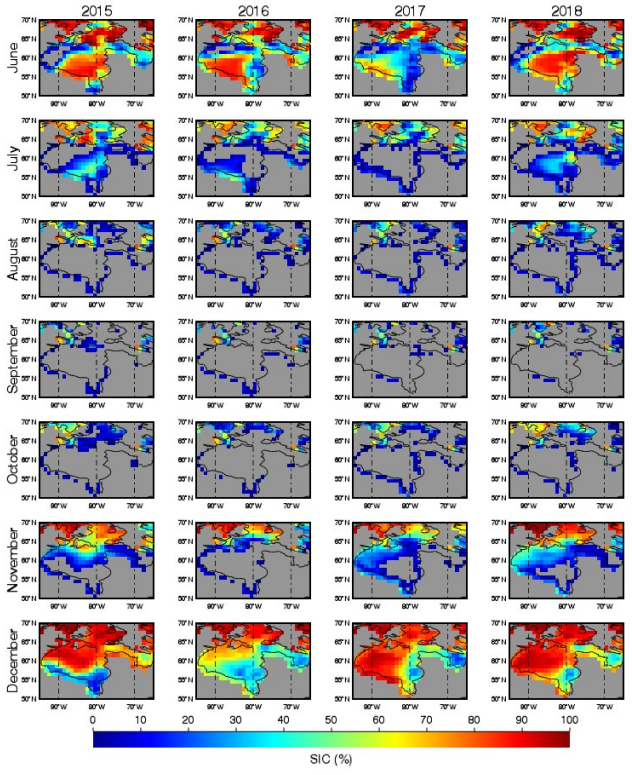
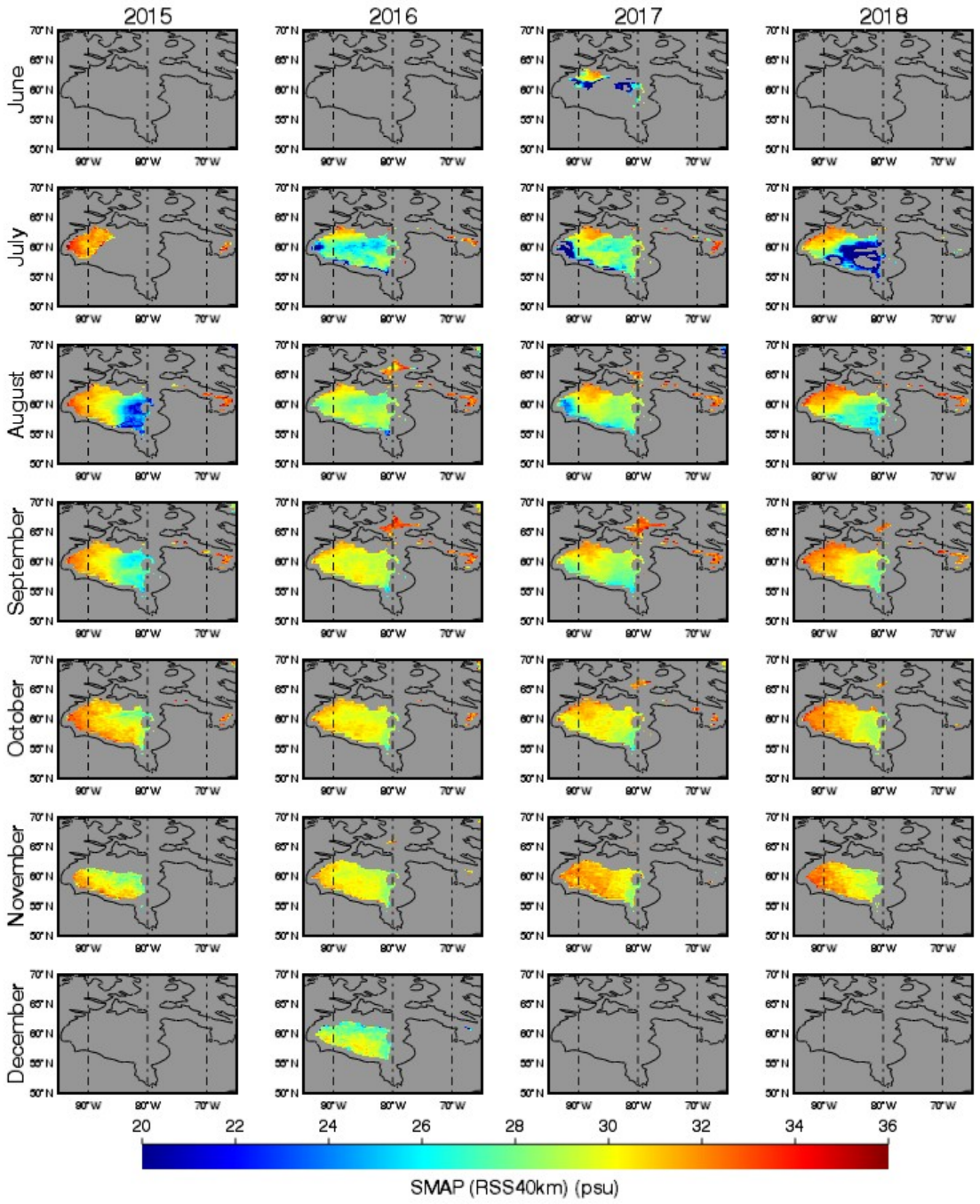
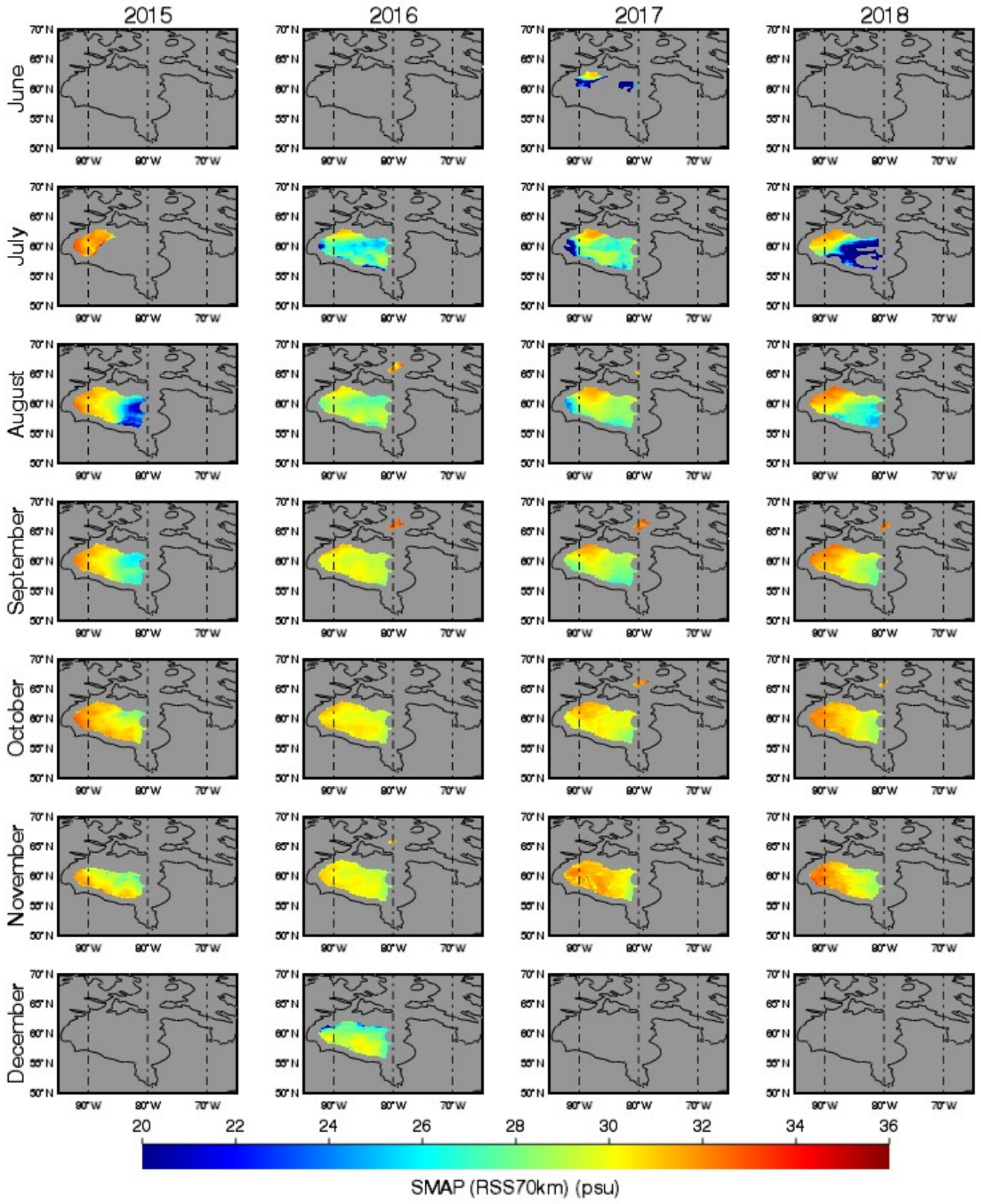


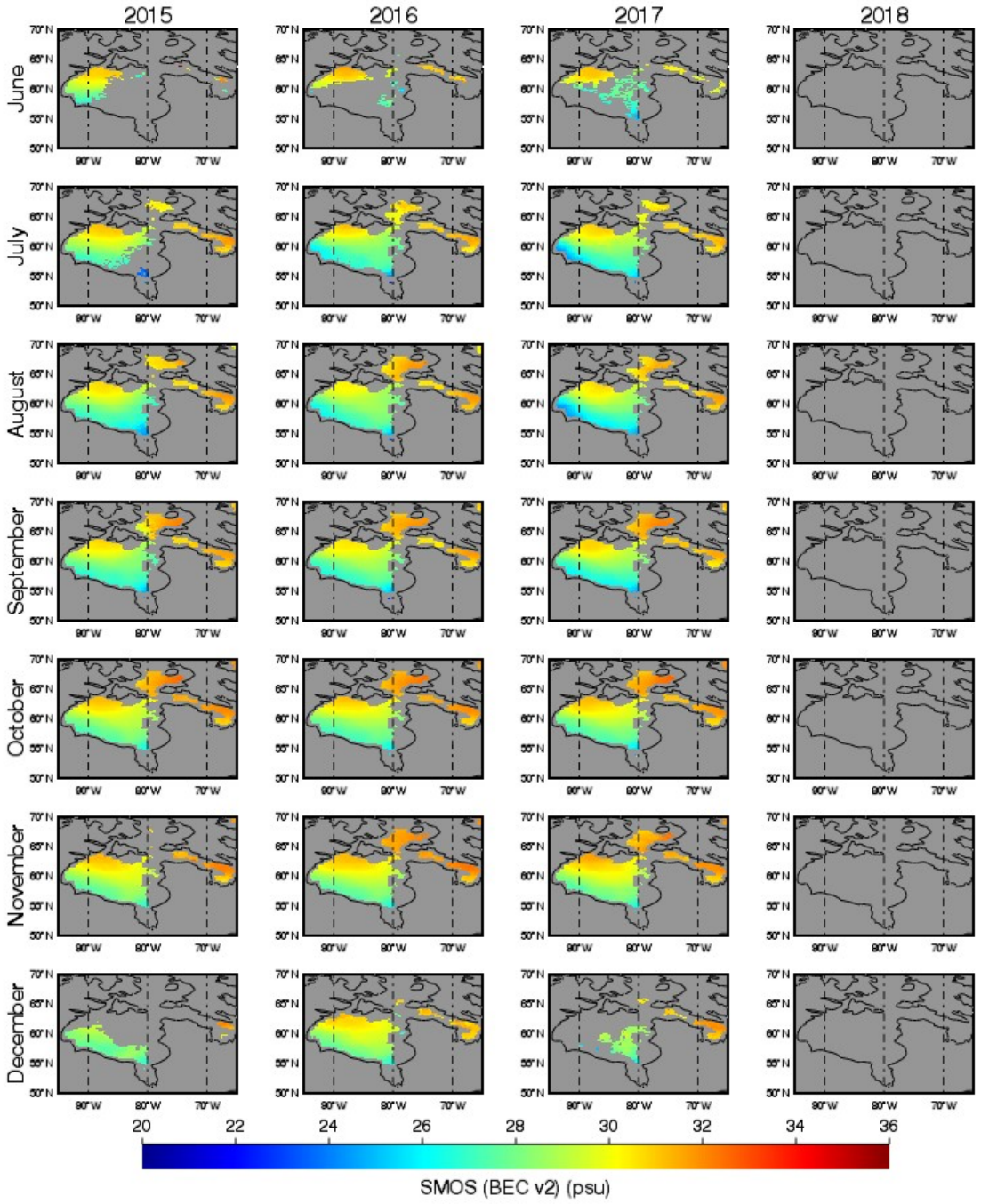
SMAP RSS V2 40km



SMAP RSS V2 70km



SMOS BEC V2


2015
2016
2017
2018
June
July
August
September
October
November
December
70°N
65°N
60°N
55°N
50°N
90°W
80°W
70°W
20
22
24
26
28
30
32
34
36
SMOS (BEC v2) (psu)

SMOS LOCEAN debiase V3